SPAR Model Development Program

RES/DRA

Background

The objective of the Standardized Plant Analysis Risk (SPAR) Model Program is to develop standardized risk analysis models and tools that staff analysts use in many regulatory activities, including the Accident Sequence Precursor (ASP) Program and Phase 3 of the Significance Determination Process (SDP). The SPAR models have evolved from two sets of simplified event trees initially used to perform precursor analyses in the early 1980s. Today's SPAR models for internal events are far more comprehensive than their predecessors. For example, the revised SPAR models include a new, improved loss of offsite power (LOOP)/station blackout module; an improved reactor coolant pump seal failure model; and updated estimates of accident initiator frequencies and equipment reliability based on more recent operating experience data.

The SPAR models consist of a standardized, plant-specific set of risk models that use the event-tree/fault-tree linking methodology. They employ a standard approach for event-tree development as well as a standard approach for input data for initiating event frequencies, equipment performance, and human performance. These input data can be modified to be more plant- and event-specific when needed. The system fault trees contained in the SPAR models generally are not as detailed as those contained in licensee probabilistic risk assessments (PRAs). To date, the U.S. Nuclear Regulatory Commission (NRC) staff has completed 78 SPAR models to represent all 104 commercial operating units and benchmarked them against licensee PRAs during the onsite quality assurance reviews of these models.

In August 2000, the staff initiated the SPAR Model Development Plan to address the following modeling issues:

- Internal initiating events during full-power operation.
- Internal initiating events during shutdown operations.
- External initiating events (including fires, floods, and seismic events).
- Calculation of large early release frequency (LERF).

The staff initiated the risk assessment standardization project (RASP) in February 2004. The primary focus of RASP is to standardize risk analyses in SDP Phase 3, ASP, and Management Directive (MD) 8.3, "NRC Incident Investigation Program." Under this project, the staff initiated the following activities:

- Enhancing SPAR models to be more plant specific and enhance the codes used to manipulate the SPAR models.

- Documenting consistent methods and guidelines for risk assessments of internal events during power operations, internal fires and floods, external events (e.g., seismic events and tornadoes), and internal events during shutdown operations.

- Providing on-call technical support for licensing and inspection issues.

SPAR Model Program Status

The SPAR Model Program continues to play an integral role in the ASP analysis of operating events. Many other agency activities, such as the SDP analyses, MD 8.3 evaluations, and the Mitigating Systems Performance Index, involve the use of SPAR models. New SPAR models are under development in response to staff needs for assessing plant risk during shutdown operations and external events and for assessing accident progression to the plant damage state level.

In conformance with the SPAR Model Development Plan, the staff has completed the following activities in model and method development since the previous status report (SECY-09-143, "Status of the Accident Sequence Precursor Program and the Development of Standardized Plant Analysis Risk Models," dated September 29, 2009) as described below.

Transition of SPAR Models to SAPHIRE Version 8

In fiscal year (FY) 2010, the 77 SPAR models representing the 104 operating commercial nuclear power plants (NPPs) were revised and augmented to take advantage of the new features and capabilities of SAPHIRE Version 8. Model enhancement included improved modeling of common-cause failure events and handling of recovery rule linking, documentation, and parameter data updates. In addition, the staff continues to provide technical support for SPAR model users and risk-informed programs. The staff also completes about a dozen routine SPAR model updates annually.

Technical Adequacy of SPAR Models

The staff implemented an updated SPAR Model Quality Assurance Plan covering the SPAR models in 2006. The main objective of this plan is to ensure the SPAR models continue to be of sufficient quality for performing event assessments of operational events in support of the staff's risk-informed activities. The staff has processes in place to verify, validate, and benchmark these models according to the guidelines and standards established by the SPAR Model Program. As part of this process, the staff performs reviews of the SPAR models and results against the licensee PRA models. The staff also has processes in place for the proper use of these models in agency programs such as the ASP Program, the SDP, and the MD 8.3 process. These processes are documented in the RASP handbook.

In addition, the staff, with the cooperation of industry experts, performed a peer review of a representative boiling-water reactor (BWR) SPAR model and pressurized-water reactor SPAR model in accordance with American National Standard, ASME RA-S-2002, "Standard for Probabilistic Risk Assessment for Nuclear Power Plant Applications," and Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities." The staff has reviewed the peer review comments and has initiated projects to address these comments, where appropriate. This effort is planned to be completed in 2013.

SPAR Models for the Analysis of External Events

The staff previously completed a total of 15 SPAR external event (SPAR-EE) models. The staff continues to work with the Office of Nuclear Reactor Regulations (NRR) and the Office of New Reactors (NRO) to identify needed enhancements to the SPAR-EE models. One significant upcoming activity is the incorporation of internal fire scenarios from the National Fire Protection

Association 805, “Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,” pilot applications into the SPAR models. Three of the SPAR-EE models were used in identifying and evaluating severe accident sequences for the consequential steam generator tube rupture project in support of the Steam Generator Action Plan. The SPAR-EE models also were recently used to provide background information to NRR on the impact of assessing external hazard risk in 10 CFR 50.65 maintenance risk assessments.

SPAR Models for Analysis of Internal Initiating Events during Shutdown Operation

The staff places a priority on creating methods and guidance for the risk assessment of shutdown events, with emphasis on SDP Phase 3 analyses. In FY 2009, the staff developed a detailed shutdown model maker guideline document to provide consistent guidance for the construction of shutdown SPAR (SPAR-SD) models. Two new SPAR-SD models were developed using the modeling guidelines, resulting in a total of seven shutdown SPAR models available to support SDP Phase 3 analyses. The work will continue in FY 2011 to create one new shutdown SPAR model, bringing the total number of SPAR-SD models to eight.

MELCOR Thermal Hydraulic Analysis for SPAR Model Success Criteria

The staff has performed MELCOR analyses, using input decks developed under the State-of-the-Art Reactor Consequence Analysis Project, to investigate success criteria associated with specific Level-1 PRA sequences. In some cases, these analyses confirm the existing technical basis and in other cases they support modifications that can be made to increase the realism of the agency's SPAR models.

To date, calculations have been performed for a number of sequences for the Peach Bottom and Surry plants. These results will be incorporated in the technical bases supporting the Surry and Peach Bottom SPAR models, and some results can be readily extended to other plants. The Office of Nuclear Regulatory Research (RES) is continuing to pursue opportunities for broadening the scope of this effort in terms of the types of sequences being investigated, as well as the applicability of the work to more plants. This includes the planned development of additional MELCOR input models, the investigation of Level-1 PRA end-state characterization (e.g., realism of core damage surrogates), and planned interactions with the Electric Power Research Institute (EPRI).

This effort directly supports the agency's goal of using state-of-the-art tools that promote effectiveness and realism. Project plans and results are being communicated to internal and external stakeholders via mechanisms such as the Regulatory Information Conference and the industry’s Modular Accident Analysis Program Users’ Group.

Additional SPAR Model Activities

SAPHIRE Version 8

SAPHIRE Version 8, released in April 2010, includes features and capabilities that are new or improved over Version 7 to address new requirements for risk-informed programs. User interfaces were developed for performing:

- SDP Phase 2 analyses with the SPAR models.
- Condition assessments for SDP Phase 3 and ASP analyses, and MD 8.3 evaluations.

- Initiating event assessments for ASP analyses and MD 8.3 evaluations.
- Other types of PRA analyses requiring more significant modeling or data revisions.

Features and capabilities also have been improved for SPAR model development and use. Enhanced SPAR models for internal events during power operations have been developed to use the new SDP Phase 2 analysis interface. A new data input method and code improvements to develop and run the SPAR-EE models was developed. New capabilities to model and analyze LERF PRA models have been incorporated. SAPHIRE Version 8 also includes the capability to perform phase mission time analysis that is also useful for modeling within the SPAR-SD models. In addition, SAPHIRE Version 8 has been designed with unique capabilities to use the SPAR models in an integrated manner (i.e., different model types such as internal and external events models combined into one model). Improved PRA methods also have been implemented for common cause failure modeling and for sequence solving. Finally, the software's general functionality has been enhanced, and the interface layout has been made more user-friendly.

SAPHIRE Version 8 was developed closely with the user community. For example, in developing the SDP user interface, pilot training classes were provided to NRC end users. The staff also widely participated in testing beta versions and provided feedback for consideration in its development. Moreover, an NRC internal peer review assessed the software requirements. In addition to these types of quality assurance activities, independent verification and validation and acceptance testing were performed for SAPHIRE Version 8.

Increased use of SAPHIRE Version 8 for NRC PRA activities is anticipated as the SPAR models are transitioned from the SAPHIRE Version 7 format, and as users become trained on its new features and capabilities. User feedback will continue to be addressed.

Audit by the NRC Office of Inspector General

The NRC Office of the Inspector General (OIG) completed an audit report, OIG-06-A-24, "Evaluation of the NRC's Use of Probabilistic Risk Assessment in Regulating the Commercial Nuclear Power Industry," dated September 29, 2006, which made the following three recommendations:

- Develop and implement a formal, written process for maintaining PRA models that is sufficiently representative of the as-built, as-operated plant to support model uses.

- Develop and implement a fully documented process to conduct and maintain configuration control of PRA software.

- Conduct a full verification and validation of SAPHIRE Version 7.

Recommendations 1 and 2 were previously addressed by the staff and closed. The corrective actions required to resolve Recommendation 3 were completed with the release of SAPHIRE Version 8 in April 2010.

Evaluation of B.5.b Strategies to Mitigate Severe Accidents

This project is in support of Staff Requirements Memorandum COMGBJ-06-0004, dated April 14, 2006. The objective of this project is to evaluate the change in risk of the 104 NRC licensed

commercial NPPs based on the implementation of mitigation strategies required by Section B.5.b of Commission Order EA-02-026, dated February 25, 2002, if those mitigation strategies are used by the licensee to mitigate reactor accidents typically modeled in the SPAR models. An evaluation of 52 SPAR models has been completed as part of the first two phases of this project. The third and final phase will result in the evaluation of the remaining 25 SPAR models. This project is on schedule to be completed in October 2010.

New Reactor SPAR Models

Prior to new plant operation, the staff may need to perform risk assessments to confirm PRA results provided in licensing submittals or to evaluate risk-informed applications. Once the plants begin operation, the results from licensee PRAs or independent assessments using SPAR models may be used by the NRC staff for the evaluation of operational findings and events similar to the assessments performed for current operating reactors.

During FY 2010 the staff developed a design-specific internal events SPAR model for the Advanced Boiling-Water Reactor (ABWR) design reactor design. As part of the SPAR model development, the requisite supporting documentation was also completed. The first draft of the ABWR model has been provided to NRO for review. The staff also plans to initiate work on developing a design-specific internal events SPAR model for the US Advanced Pressurized Water Reactor. Because design standardization is a key aspect of the new plants, it should only be necessary to develop one SPAR model for each of the new designs.

The AP1000 model was completed in February 2010 and has been transitioned to a routine maintenance status. It has also been optimized for SAPHIRE Version 8.

Cooperative Research for PRA

The staff has executed an addendum to the memorandum of understanding with EPRI to conduct cooperative nuclear safety research for PRA. Several of the initiatives included in the addendum are intended to help resolve technical issues that account for the key differences between NRC SPAR models and licensee PRA models. The staff also continues to work with the National Aeronautical and Space Administration to address PRA issues of mutual interest. In addition, the NRC has utilized the cooperative agreement and grant program to establish collaborative PRA research projects with the University of Maryland and the Massachusetts Institute of Technology.

The objective of this effort is to work with the broader PRA community to resolve PRA issues and to develop PRA methods, tools, data, and technical information useful to both NRC and industry. The agency has established working groups that include support from RES, NRR, NRO, and the Regions. Initial cooperative efforts include the following:

- Support system initiating event analysis.
- Treatment of LOOP in PRAs.
- Treatment of uncertainty in risk analyses.
- Standard approach for injection following BWR containment failure.
- Standard approach for containment sump recirculation during small and very small loss-of-coolant accident.
- Human reliability analysis.
- Digital instrumentation and control risk methods.

- Advanced PRA methods.
- Advanced reactor PRA methods.

Significant efforts have been made in the past year in the areas of support system initiating event analysis, treatment of LOOP in PRAs, and treatment of uncertainty in risk analysis. For example, in the area of support system initiating event analysis, the staff and industry have come to agreement on a common approach to modeling support system initiators and worked together to resolve common cause issues that significantly affect model quantification results. The staff plans to use the support system initiating event and treatment of LOOP in PRAs methodologies to enhance the SPAR models. These methodologies are planned to be implemented in the SPAR models as one of the activities associated with addressing the peer review comments. The staff plans to continue these cooperative efforts with EPRI and other stakeholders to address the remaining issues over the next several years.

Upcoming Activities

- The staff will continue to implement enhancements to the internal event SPAR models for full-power operations. Anticipated enhancements include incorporating new models for support-system initiators and revised success criteria based on insights from thermal-hydraulic analyses. The staff also is working with industry representatives to resolve other PRA technical issues common to both licensee PRAs and NRC SPAR models. In support of this effort, the memorandum of understanding addendum on PRA with the Electric Power Research Institute has been extended through 2016.

- The staff has reviewed the SPAR model peer review comments. A project plan is being developed to address peer review comments, where appropriate, and is planned to be completed in 2013. The main objective of this effort is to ensure the SPAR models continue to be of sufficient quality for performing SDP Phase 3, ASP, and MD 8.3 event assessments in support of the staff's risk-informed activities.

- The staff will use information obtained as part of the National Fire Protection Association 805 pilot application process to create two new SPAR fire models with updated fire scenarios.

- The staff will continue to evaluate the need for additional SPAR model capability (beyond full-power internal events) based on experience gained from SDP, ASP, and MD 8.3 event assessments.

- The staff will continue the development of SPAR models for new reactors to allow confirmation of PRA results presented in licensing submittals, evaluation of risk-informed applications prior to new plant operation, and assessment of operational findings and events once operation commences. The next new reactor SPAR model planned to be developed is for the Advanced PWR.

In summary, the SPAR Model Program is continuing to develop and improve independent risk analysis tools and capabilities to support the use of PRA in the agency's risk-informed regulatory activities.